Composite Materials
2018; 2(2): 49-54
http://www.sciencepublishinggroup.com/j/cm
doi: 10.11648/j.cm.20180202.12

Hybridisation of Carbon Black: Cashew Nut Shell Powder as Fillers on the Mechanical Properties of Natural Rubber Composites

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To cite this article:
Okele Abdul-wahab Ilavbare, Gimba Casmir Emmanuel, Mamza Paul Andrew Ptileri, Abba Hamza. Hybridisation of Carbon Black: Cashew Nut Shell Powder as Fillers on the Mechanical Properties of Natural Rubber Composites. *Composite Materials*. Vol. 2, No. 2, 2018, pp. 49-54. doi: 10.11648/j.cm.20180202.12

Received: December 4, 2018; **Accepted**: December 26, 2018; **Published**: January 22, 2019

Abstract: Cashew nut shell powder and carbon black were used as hybrid fillers to reinforce Natural rubber compound. The fillers; cashew nut shell powder and carbon black were loaded at 0, 30:0, 25:5, 20:10, 15:15, 10:20, 5:25 and 0:30 respectively. The cashew nut shell was carbonized and characterized for particle size, pH and moisture content, the results were 316.7d.nm, 8.13 and 0.58% respectively. The mechanical analysis viz; tensile strength, hardness, compression set and abrasion resistance were also carried out, the obtained results showed that hybridized compound with CNSP25/CB5 gave the best tensile strength of 5 Mpa as against the unfilled compound with 0.3 Mpa, this was also the same trend with the abrasion resistance with compound hybridized with CNSP25/CB 5 with the best abrasion resistance of 0.54% and was also the same compound with the best hardness result with hardness value of 47 IRHD, similar result was also obtained for compression set with the same composition with the best compression result of 6.3% compression set.

Keywords: Hybridisation, Cashew Nut Shell Powder, Carbon Black, Particle Size and Nano

1. Introduction

In this twenty first century, renewable and cheap material has now been utilized in the processing of rubber compounds to replace the other commercially utilized materials such as carbon black which is derived from the hydrocarbons and it is exhaustible and expensive. Natural rubber which is the largely commercially used in the rubber industry still found its usefulness because of its peculiar properties, however, in its raw state, natural rubber is not suitable for use in any given application because of their viscoelasticity (tendency of both plastic and elastic behaviour) [8].

It is likely that during this century polymers based on renewable materials will gradually replace industrial polymers based on petrochemicals. Most biopolymers cannot yet compete with their petrochemical equivalents, and significant efforts on raw materials, processing technology, and applications are still required to change this situation. [2].

Natural rubber and synthetic rubber are converted to serviceable products by combining them with fillers. Fillers are materials which when added to rubber mix enhance the properties. These properties are physical in nature which includes hardness, tensile strength, flex fatigue, stiffness and to some extent, the chemical properties. Fillers improve the processing characteristics, reduce cost and also acts as auxiliary components necessary for vulcanisate. Fillers can either be reinforcing, semi-reinforcing or non-reinforcing. Reinforcing fillers enhance the physical properties of the cured article. There are also non-reinforcing fillers. They reduce cost and improve processing characteristics for example by reducing nerve in the processing of rubber. Non-reinforcing fillers have little or no effect on the physical properties of the rubber. Examples of these include talc, barites, mica powder, whiting and china clay. Semi-reinforcing fillers are partially reinforcing. These include soft clay, calcium carbonate and antimony, [1].

Cashew nut shell constitutes environmental menace in the southern part of Nigeria, therefore the need to put it to useful application in rubber as rubber compounding cannot be achieved without the use of fillers. Locally sourced potential fillers may modify the mechanical properties of natural rubber vulcanisates, [3]. The process of producing carbon black requires tremendous energy utilization, heavy infrastructure setup and constitutes a heavy source of environmental pollution and it is also carcinogenic, [8].

Agricultural by-products; maize cobs, cocoa pod husk, sugar cane chaff, rice husk, plantain peel etc. are low cost materials and readily available in large quantity for use everywhere, of which well over 300 million tones are produced annually. [6].

Material Scientists now focus on the use of natural materials for the development of composite materials. [9]. It is known that in the case of filled vulcanized, the efficiency of reinforcement depends on a complex interaction of several filler related parameters. [4]. Filling carbon blacks in elastomers and plastics also reduces the cost of the end product and modifies the electrical and optical properties of the polymer matrix. [5]. Every recipe contains a number of components, each having a specific function either in the processing vulcanization or end use requirement of the product. [3].

Rubbers make up a class of polymers known for their ability to undergo large recoverable deformations. [7].

The major aim of this work is to see how hybridization of fillers can be used to improve the mechanical properties of natural rubber composites

2. Materials, Equipment and Methodology

2.1. Materials

Cashew nut shell was locally sourced from Auchi community of Edo State. Natural rubber was obtained from Rubber Research Institute of Nigeria, Iyanomo, Benin city, Edo State. All other compounding additives used (zinc oxides, stearic acid, trimethylquinoline, sulphur, mercaptobenzo disulphide, carbon black) are of analytical grades and products of British Drug House (BDH), England.

2.2. Equipment

The equipment used are Endocott test sieve shaker, by Endocott test sieve ltd., London, Ball Miller by Pascal Engineering Co. Ltd. Sussex, England, Advanced Material Testing Machine, Zwick/Roell, India, Muver Francisco Irles Hardness tester model 5019, Wallace compression set machine, model C84025/2, Setra abrasion test equipment, model 11884 and Two roll mill, Reliable Rubber and Plastics Machinery, model 5189.

Table 1. *Formulation for the rubber compound.*

S/No	Ingredients	Formulations (PPHR) grams							
		1	2	3	4	5	6	7	8
1	Natural rubber	100	100	100	100	100	100	100	100
2	Zinc oxide	5	5	5	5	5	5	5	5
3	Stearic acid	2	2	2	2	2	2	2	2
4	TMQ	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
5	MBT	3	3	3	3	3	3	3	3
6	CB/CNSP	00	0/30	5/25	10/20	15/15	20/10	25/5	30/0
7	Processing oil	2	2	2	2	2	2	2	2
8	Sulphur	3	3	3	3	3	3	3	3

Key: TMQ: Trimethyl quinoline, MBT, CB: Carbon Black, CNSP: Cashew Nut shell powder.

2.3. Methods

2.3.1. Preparation and Characterization of Nano Filler

Cashew nut shell was winnowed to remove sand particles and other adhering foreign bodies and then washed. The washed cashew nut shell was placed in the planetary mill with a spherical grinding media which consists of planetary balls (< 0.1mm diameter) made of hardened steel (0.24 to 0.95cm diameter). The cashew nut shell and the grinding media were placed in a stationary tank followed by an agitation with an armed shaft rotating at 250rpm. The forces of shear and impact exerted by the grinding media on the cashew nut shell reduced it to a dispersion of fine powder. The resultant slurry formed was discharged, air-dried and further oven-dried. The cake was further extracted with N-hexane to discard off the oil in the cashew nut shell and the residue was ball milled using the top-down technique (i.e. critical speed grinding under a continuous process of approximately 48hrs) to a fine particle size. Standard tests method was used to characterize the semi-nano powder for moisture content (ASTM 1509) at 105°C, pH (ASTM 1512) and X-ray florescence.

2.3.2. Compounding of the Composites

The compounding of the rubber with other additives were done using a laboratory two roll mill in accordance with ASTM D3184-80 method at temperature of 70 ± 5°C, followed by in-situ moulding and curing at 130°C with a hydraulic press machine

2.3.3. Tensile Strength

These tests were conducted in accordance to ASTM D412. Tensile tests were carried out at room temperature using an Advance Material Testing machine model 3366 with a load cell 1kN. Pre-moulded dumbbell shaped specimens with dimensions of 50 X 8 X 4 mm^3 were used to perform the experiment at a loading speed of 2000 mm/min.

2.3.4. Hardness Test

The hardness test of a rubber is the relative resistance of the surface to indentation by an indentor of specified dimension under a specified load. Hardness of the vulcanisates was determined by standard dead load method (BS903 part A 26).

2.3.5. Abrasion Resistance

Wallace Akron tester was used in accordance with BS method

Abrasive resistance index = (S) 1000/ T

2.3.6. Compression Set

Wallace compression set machine (Mode/Ref No (2, H_2^{50}) was used to determine the compression set of the vulcanizates. Compression set % = t_0- tr/t_0 X 100

3. Results and Discussion

3.1. Results

Results

			Size (d.nm)	% Volume:	St Dev (d.nm)
Z-Average (d.nm):	1249	Peak 1:	316.7	100.0	81.56
PdI:	0.939	Peak 2:	0.000	0.0	0.000
Intercept:	0.882	Peak 3:	0.000	0.0	0.000
Result quality	Refer to quality report				

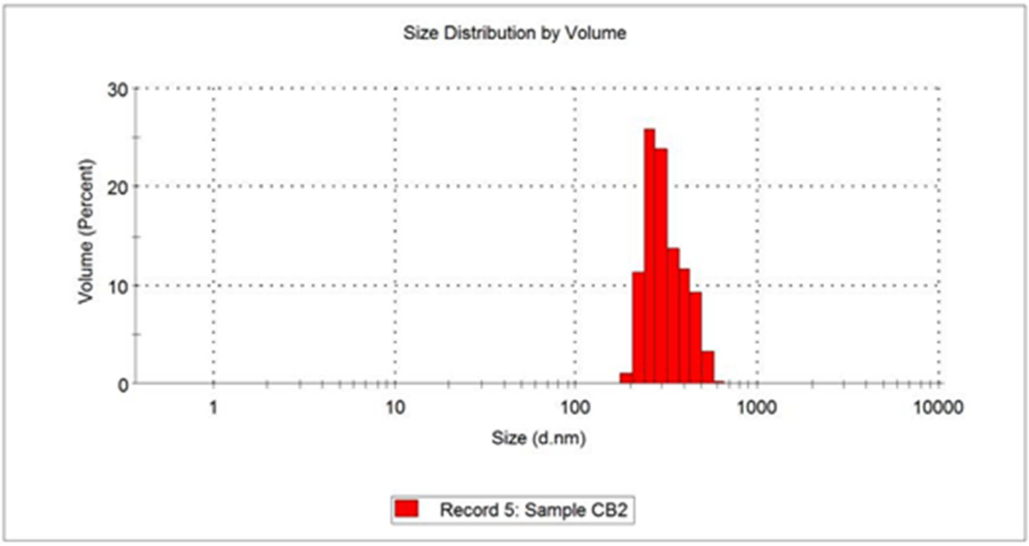

Figure 1. *Particle size analysis of Cashew nut shell powder.*

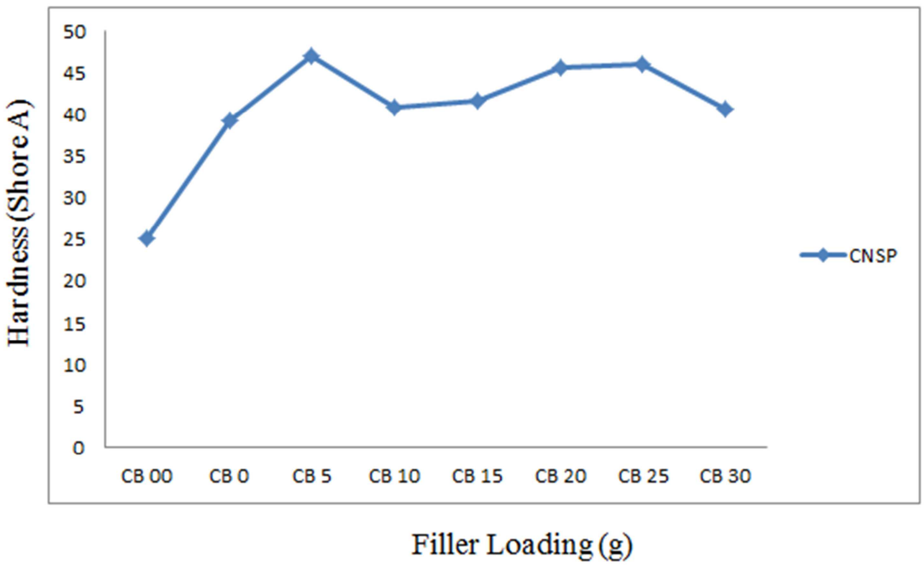

Figure 2. *Effect of hybridization on hardness.*

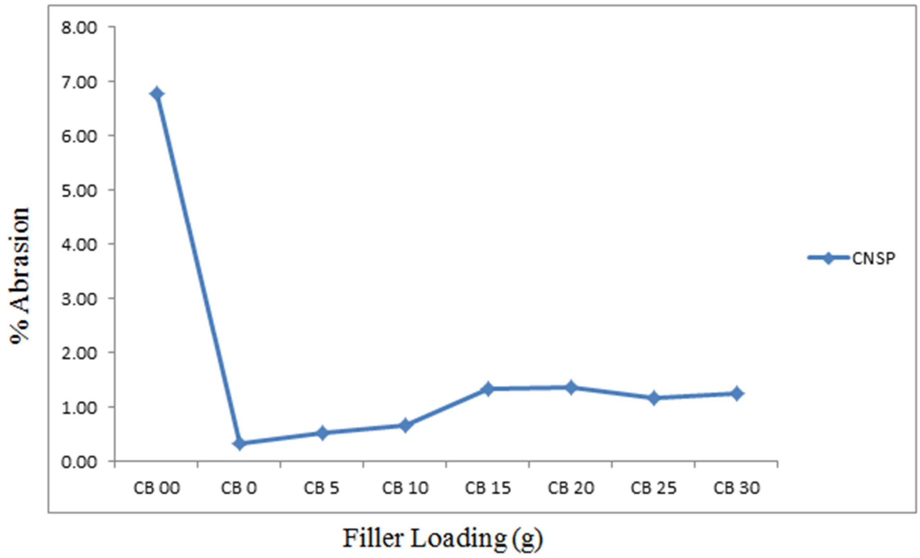

Figure 3. *Effect of hybridization on Abrasio*

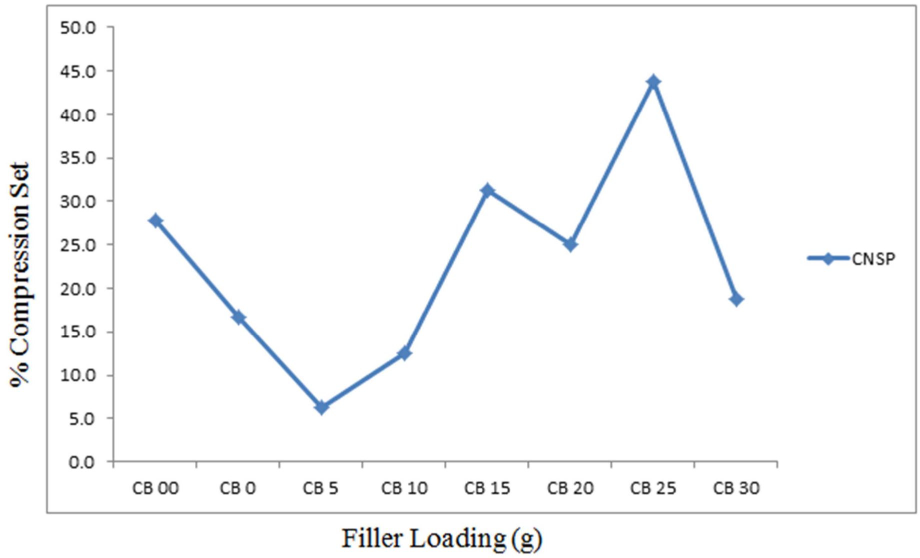

Figure 4. *Effect of hybridization on Compression set.*

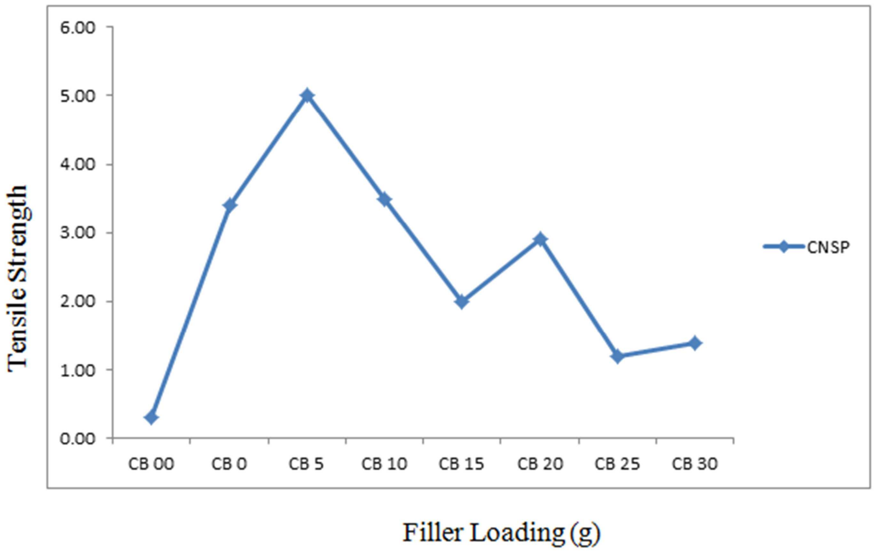

Figure 5. *Effect of hybridization on Tensile strength.*

3.2. Discussion

The filler characterization reveals that cashew nut shell powder has a pH value of 8.13 and with moisture content of 0.58%, the particle analysis was carried out and the particle range is 316.7d.nm at 100% making it a semi nano filler as it fell beyond the nano range of 1-100nm using a dynamic light scattering.

The mechanical properties of natural rubber vulcanisates filled with hybrid fillers (carbon black/cashew nut shell powder) were analysed and the compositions filled were 0, 0:30, 5:25, 10:20, 15:15, 20:10, 25:5, and 30:0 respectively, for carbon black and cashew nut shell powder.

The hardness of the vulcanisates reveals an increase in the hardness values as the amount of carbon black dosed was increasing form 0-25 pphr. Unlike the conventional methods of increasing filler loadings and hardness value will increase, in this case a maximum loading of 30 pphr was generally used in this formulation.

The best hardness loading in this formulation is at 5pphr of carbon black to 25 pphr cashew nut shell powder which revealed 47 IRHD against the control sample without filler with a hardness value of 25 IRHD, but in comparing it to the loadings at 30pphr of carbon black to 30pphr of cashew nut shell powder, carbon black reveals a higher hardness value of 41 IRHD to cashew nut shell powder with a hardness value of 39 IRHD and this generally reveals that hybridizing both cashew nut shell and carbon black will give considerably better and required hardness results than using them as individual fillers.

The abrasion resistance of the hybridized composites reveals an increase in the percentage abrasion as the amount of carbon black was increased from 5pphr to 30pphr with percentage abrasion resistance of 0.54% at CB5/CNSP25 and with the lowest abrasion resistance in compound with CB15/CNSP15 and CB20/CNSP10 with percentage abrasion of 1.34% and 1.36% respectively, but comparing the composites of 30pphr of CB and that of CNSP, the CNSP gave a better abrasion resistance than that of the CB with percentage abrasion of 0.35% of CNSP to 1.26% of CB.

The percentage compression set reveals a drop in the compression set as CB5pphr was introduced showing a percentage compression set of 6.3% which happens to be the best compression set of the hybridized composites with the unfilled compound with percentage compression set of 27.8%, after which the compression set began to increase with increase in CB, however compound filled with only 30pphr of cashew nut shell powder reveals a better compression set than that of 30 pphr filled carbon black with 16.7% to 18.8% respectively.

The results of the tensile strength of the hybrid compound were not too far from what were observed from other mechanical test which showed improvement from the unfilled compound to the compound filled with CB5/CNSP25 which gave the best tensile strength with 5 Mpa against 0.3 Mpa of the unfilled compound. However there begin a drop in the tensile strength as the amount of CB filled increased form 5pphr to 15pphr and later increased at 20pphr of CB before if eventually experienced decrease again. The hybrid compound filled with 30pphr of CB had a lower tensile strength to that of CNSP with tensile strength of 1.4 Mpa to 3.4 Mpa respectively which is an indication of reinforcement of CNSP at nano level.

4. Conclusion

The work as presented in this paper is preliminary and the effects of semi-nano hybridization of fillers (Carbon black and cashew nut shell powder) were investigated. The main aim of the research was to see how semi-nano particles of agro-waste can be hybridized with carbon black N330 to reduce the cost of production when reinforced with natural rubber.

The obtained results reveals that semi-nano CNSP is a potential reinforcing filler when processed and hybridized with carbon black, this studies indicated that by further reducing the particle size of CNSP will further make it a better reinforcing filler as an agricultural waste hence converts waste to wealth as the best tensile strength result obtained was at 5g CB/25g CNSP which will be a great relief to the use of carbon black that is exhaustible and further use of CNSP as a renewable filler.

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